35. (New) An apparatus according to Claim 19, wherein said light source comprises an ArF excimer laser light source.

36. (New) An apparatus according to Claim 19, wherein said inert gas comprises one of a nitrogen gas, a helium gas, and a neon gas.

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37. (New) A device manufacturing method comprising the steps of:

providing an exposure apparatus as recited in Claim 19; and

performing an exposure process by use of the exposure apparatus.--.

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REMARKS

This application is a continuation of copending Application No. 09/240,839, filed February 1, 1999.

The specification has been amended to correct minor informalities and to reflect the continuing status of this application. Also, a new abstract is presented in accordance with preferred practice. No new matter has been added.

Claims 19 through 37 are now presented in lieu of claims 1 through 18, which have been canceled without prejudice or disclaimer. Claim 19 is the sole independent claim.

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Applicants submit that claims 19 through 37 patentably define the features of the exposure apparatus and the device manufacturing method of the present invention. Therefore, Applicants submit that the instant application is in condition for allowance.

Favorable consideration and an early passage to issue are requested.

Applicants' undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE TO SPECIFICATION

A new paragraph has been added to page 1 before line 1.

The paragraph starting at page 1, line 5 has been amended as follows.

This invention relates generally to an exposure apparatus which uses, as an exposure beam, short wavelength electromagnetic waves such as X-rays or ultraviolet rays from an excimer laser, for example. More specifically, the invention is concerned with such an exposure apparatus, a device manufacturing method using the same, and a method of [clearing] cleaning an optical element of such an exposure apparatus.

The paragraph starting at page 1, line 13 has been amended as follows.

In projection exposure apparatuses for the manufacture of semiconductor integrated circuits, light of various wavelength bands is projected as an exposure beam to a substrate. As for such an exposure beam, examples are e-line (wavelength λ = 546 nm), g-line (λ = 436 nm), h-line (λ = 405 nm), i-line (λ = 365 nm), a KrF excimer laser (λ =

248 nm), an ArF exciter laser (λ = 193 nm), and [X rays] X-rays.

The paragraph starting at page 1, line 21 has been amended as follows.

An exposure beam emitted from a light source is directed by way of an illumination optical system for illuminating a reticle and a projection optical system (projection lens) for imaging a fine pattern formed on the reticle upon a photosensitive substrate, whereby the fine pattern is lithographically transferred to the photosensitive substrate. In such exposure apparatuses, miniaturization of the pattern linewidth has forced further improvements of throughput and resolution. Also, an exposure beam of a higher power has been required and, on the other hand, shortening of the wavelength band of an exposure beam has been required.

The paragraph starting at page 2, line 7 has been amended as follows.

It is known that when an exposure beam of i-line (wavelength λ = 365 nm) or a shorter wavelength is used, due to shortening of the wavelength, impurities in the air photochemically may react with oxygen. The product (blurring material) of such a reaction may be deposited on an optical

element (lens or mirror) of the optical system, causing non-transparent "blur".

The paragraph starting at page 2, line 15 has been amended as follows.

As regards such a blurring material, in a case where [sulfurous] sulfuric acid SO_2 absorbs light energy and it is excited thereby, a typical example may be ammonium sulfate $(NH_4)_2SO_4$ produced by a reaction (oxidization) with oxygen in the air. When such ammonium sulfate is deposited on the surface of an optical element such as a lens or mirror, the above-described "blur" results. Then, the exposure beam is scattered or absorbed by the ammonium sulfate, so that the transmission factor of the optical system decreases. This causes a large decrease of light quantity (transmission factor) upon the photosensitive substrate, and thus a decrease of throughput.

The paragraph starting at page 3, line 1 has been amended as follows.

Particularly, for an ArF excimer laser (193 nm) or X-rays which are in a very short wavelength region, the exposure beam may cause a strong photochemical reaction. Thus, the above-described problems [is] are very serious.

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The paragraph starting at page 3, line 8 has been amended as follows.

Japanese Laid-Open Patent Application, Laid-Open No. 216000/1994 shows an arrangement wherein a barrel having mounted therein a glass member such as a lens is provided in a casing of a closed structure, and wherein the inside of the casing is filled with an inert gas, thereby to solve the problem such as described above.

The paragraph starting at page 3, line 15 has been amended as follows.

However, it has been found that, in such an example using inert gas, an optical element within the barrel or casing of the illumination optical system may be contaminated by organic molecules. These molecules may be those of any solvent, for example, used during manufacturing and working processes of components of the illumination optical system and remaining on the components, or those of an adhesive agent used in the casing or barrel and evaporated therefrom.

The paragraph starting at page 3, line 25 has been amended as follows.

Taking the manufacturing procedure into consideration, the environmental air may be contaminated by

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organic molecules coming from an adhesive agent layer between a substrate and a photoresist, for example. These molecules may enter the casing or barrel. Even if the organic molecules are at a low concentration, particles may be decomposed due to the influence of <u>an</u> ultraviolet beam and they may be deposited on the optical element. [In] <u>On</u> that occasion, a carbon film or a film containing carbon will be produced on the element surface.

The paragraph starting at page 4, line 9 has been amended as follows.

Japanese Laid-Open Patent Application, Laid Open No. 209569/1995 shows an arrangement wherein, when an inert gas is supplied into a projection optical system, a small amount of ozone is mixed into the inert gas, such that an inert gas containing ozone is supplied to an optical system. The optical element is irradiated with an exposure beam in a gas ambience containing ozone and, due to <u>an</u> ozone cleaning effect, decomposition of organic molecules on the surface of the optical element as well as deposition of [product] <u>products</u> of <u>the</u> decomposition thereon are prevented.

The paragraph starting at page 5, line 11 has been amended as follows.

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It is another object of the present invention to provide a device manufacturing method using such an exposure apparatus and/or a method of cleaning an optical element of an exposure apparatus.

The paragraph starting at page 5, line 15 has been amended as follows.

In accordance with an aspect of the present invention, there is provided an exposure apparatus, comprising: a light source for producing an exposure beam; an optical system having a closed space, for projecting the exposure beam to a substrate for exposure thereof; first supplying means for supplying an inert gas into the closed space of said optical system; and second supplying means for supplying one of oxygen and [a] clean air, so that the inert gas and oxygen can be supplied to the closed space.

The paragraph starting at page 5, line 25 has been amended as follows.

In accordance with another aspect of the present invention, there is provided a device manufacturing method comprising the steps of: [preparing] providing an exposure apparatus as recited above; and performing an exposure process by use of the exposure apparatus.

The paragraph starting at page 6, line 4 has been amended as follows.

In accordance with a further aspect of the present invention, there is provided a method of cleaning an optical element of an exposure apparatus for exposing a substrate with an exposure beam of ultraviolet rays or X-rays, projected thereto, said method comprising the steps of: supplying an inert gas containing a small amount of oxygen into a space in which the optical element is placed; projecting the exposure beam so that ozone is produced in the space; and removing an organic compound deposited on the optical element through <u>a</u> photochemical reaction by projection of the exposure beam and the produced ozone.

The paragraph starting at page 7, line 1 has been amended as follows.

Figure 2 is a sectional view for explaining an example of <u>an</u> inside structure of a barrel.

The paragraph starting at page 7, line 9 has been amended as follows.

Preferred embodiments of the present invention will now be described with reference to the accompanying drawings. In an embodiment of the present invention to be described

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below, the invention is applied to an exposure apparatus of a reduction projection type, which is generally called a stepper or a scanner.

The paragraph starting at page 7, line 16 has been amended as follows.

The exposure apparatus A1 has a major assembly which may be roughly separated into a light source 1 (ArF excimer laser light source), a light source lens system 2 which comprises an illumination optical system for transforming laser light L1, which is illumination light emitted from the light source 1, into light of a predetermined shape, and a projection lens system 5 for imaging the laser light L1, having been formed into a predetermined shape by the light source lens system 2, upon a wafer 4 (substrate) through a reticle 3. The light source 1 includes a laser control device 6 for controlling a laser output of the same. The laser control device 6 is controlled by a controller 7 (control means). The laser control device 6 functions to change the emission laser wavelength region, to be described later.

The paragraph starting at page 8, line 5 has been amended as follows.

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In this embodiment, the light source comprises an ArF excimer laser which produces ultraviolet rays. However, it may comprise a KrF excimer laser light source or, alternatively, an X-ray source for producing shorter wavelength X-rays (X-rays are referred to generally [to] as soft X-rays or vacuum ultraviolet rays, for example), such as a synchrotron radiation source or a laser plasma radiation source, for example.

The paragraph starting at page 9, line 3 has been amended as follows.

Inert gas of nitrogen gas (it may be a gas of helium or neon, for example) is supplied to an inside space 2j of the casing 2g of the illumination optical system 2, to the inside spaces of the barrels 2h and 2i, and to the spaces inside the projection lens 5 and the lens barrel as separated by lenses. Inert gas supplying device 8a is connected to these spaces through an inert gas supplying line 8b and an electromagnetic valve 8c (opening/closing valve) provided in a portion of this line. At an intermediate position on the inert gas supplying line 8b, there is an oxygen supplying line 10b connected as a branch. Through an electromagnetic valve 10c (opening/closing valve) provided in a portion of this line, an oxygen supplying device 10a is connected thereto. This enables mixture of a small amount of oxygen

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into the inert gas to be supplied. In place of pure oxygen, [a] clean air which contains oxygen may be mixed.

The paragraph starting at page 10, line 1 has been amended as follows.

The gas collected by the gas discharging means may include a small amount of residual ozone. The gas discharging device 9a may be provided with converter means for re-converting the residual ozone into oxygen. Impurities may be removed by a filter and thereafter, the oxygen thus re-converted may be circulated to the oxygen supplying device 10a, for reuse thereof.

The paragraph starting at page 10, line 16 has been amended as follows.

More specifically, in accordance with preset timing, in the stand-by state of the apparatus, the electromagnetic valve 10c of the oxygen supplying line opens so that a small amount of oxygen is mixed into the nitrogen gas. The resultant gas is supplied into the casing and barrels of the illumination optical system and also into the barrel of the projection optical system. The opening/closing of the electromagnetic valve is controlled so that the amount of oxygen supply is kept not greater than a predetermined concentration (e.g., not greater than a [a] few grams per

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$1m^3$). After the mixture gas is supplied, the electromagnetic valves 8c and 9c are closed. In the state in which the spaces are filled with a gas in which a small amount of oxygen is mixed into a nitrogen gas, projection of laser light is performed. In response to this, in these spaces, oxygen within the inert gas, filling the space, is converted into ozone through <u>a</u> photochemical reaction. Thus, in these spaces, ozone is produced first. Laser projection is continued in this state and, as a result, any organic compound deposited on optical elements (lenses, mirrors or windows) constituting the optical system is oxidized. Consequently, organic molecules on the optical element [is] <u>are</u> removed by ozone cleaning, whereby the optical element is cleaned.

The paragraph starting at page 11, line 15 has been amended as follows.

Subsequently, the electromagnetic valves on the inert gas supplying line and the gas discharging line are opened, and supply of inert gas and discharging of the gas are continued interruptedly or uninterruptedly until the inside gas is completely replaced by nitrogen gas. The series of these sequential operations [are] <u>is</u> performed in accordance with a program set in the controller beforehand. As regards the cleaning of <u>the</u> optical elements, it may preferably be made during the stand-by period of the

apparatus in which the apparatus is held inoperative, since it does not influence the throughput. Alternatively, cleaning may be made during actual operation of the apparatus.

The paragraph starting at page 12, line 2 has been amended as follows.

The efficiency of producing ozone from oxygen by light projection largely depends on the wavelength of light projected. In consideration of this, in order to assure efficient production of ozone, the wavelength of <u>the</u> exposure beam may preferably be changed, between the exposure process for a substrate and the cleaning operation for <u>the</u> optical elements. More specifically, for the cleaning operation, preferably the wavelength region may be oscillated continuously or it may be changed to <u>a</u> shorter wavelength side, by which the ozone production efficiency and thus the cleaning capacity can be improved. Changing the wavelength may be accomplished by controlling the light source actuation or by inserting wavelength changing means (such as a harmonic wave producing element, for example) into the light path, for example.

The paragraph starting at page 12, line 19 has been amended as follows.

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Figure 2 is an enlarged view of a portion of the barrel 2h of the illumination optical system, in the [neighbourhood] neighborhood of a gas blowing port of the inert gas supplying line. As regards optical elements 13a and 13b, it is expected that a large amount of organic molecules may be deposited on these elements. Thus, the structure is so arranged that the inert gas is directly blown against these optical elements. This enhances the ozone cleaning effect considerably.

The paragraph starting at page 13, line 6 has been amended as follows.

[Exposure] The exposure apparatus may include optical elements other than lenses, mirrors or windows as described. An example is a filter for transmitting only a desired wavelength of light among a broad wavelength band as emitted by a light source such as a Hg lamp or synchrotron radiation source. The advantageous effects of the present invention described above similarly [applies] apply to such an optical element.

The paragraph starting at page 13, line 18 has been amended as follows.

Figure 9 is a flow chart of a procedure for the manufacture of microdevices such as semiconductor chips

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(e.g., ICs or LSIs), liquid crystal panels, CCDs, thin film magnetic heads or micro-machines, for example.

The paragraph starting at page 13, line 23 has been amended as follows.

Step 1 is a design process for designing a circuit of a semiconductor device. Step 2 is a process for making a mask on the basis of the circuit pattern design. Step 3 is a process for preparing a wafer by using a material such as silicon. Step 4 is a wafer process which is called a pre-process wherein, by using the so prepared mask and wafer, circuits are practically formed on the wafer through lithography. Step 5 subsequent to this is an assembling step which is called a post-process wherein the wafer having been processed by step 4 is formed into semiconductor chips. This step includes <u>an</u> assembling (dicing and bonding) process and <u>a</u> packaging (chip sealing) process. Step 6 is an inspection step wherein <u>an</u> operation check, <u>a</u> durability check and so on for the semiconductor devices provided by step 5, are carried out. With these processes, semiconductor devices are completed and they are shipped (step 7).

The paragraph starting at page 15, line 9 has been amended as follows.

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In accordance with an exposure apparatus of the present invention, the problem of deposition of organic molecules on an optical element and reduction of illuminance thereby can be removed. Since the exposure beam itself to be used for the exposure process is used also for ozone production, use of an additional and a large mechanism is not necessary. Further, since ozone production is made only inside a closed space in which the optical element is disposed, there is no dangerous possibility of leakage of harmful ozone.

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